

Step-down DC/DC Converter with VR and Reset

NO.EA-128-120404

OUTLINE

The R5212D is CMOS-based PWM step-down DC/DC converter combined with a voltage regulator (VR) and a voltage detector (VD), with low supply current.

Each of these ICs consists of an oscillator, a PWM control circuit, a voltage reference unit, an error amplifier, a soft-start circuit, a current limit circuit, a phase compensation circuit, a resistor net for voltage detect circuit, an output driver transistor, and so on. A low ripple, high efficiency step-down DC/DC converter can be easily composed of this IC with some external components, or an inductor, a diode, and capacitors.

The oscillator frequency is 1.2MHz, therefore small inductor and capacitor can be used with this IC. Further, this IC equips the under voltage lockout function (UVLO). If the input voltage becomes equal or less than 2.35V (Typ.), the output of DC/DC converter turns off. However, in the A/B version, embedded voltage regulator and detector continue to operate. In the C/D version, LDO output also turns off and only the voltage detector is working.

The voltage regulator consists of a voltage reference unit, a resistor net for voltage detect circuit, an error amplifier, an output driver transistor, and so on.

The input source voltage of the built-in voltage regulator is V_{IN} pin (A/B version) or V_{OUT1} pin, the output of DC/DC converter (C/D version).

The built-in voltage detector supervises the input voltage and the output is N-channel open drain.

Power-on reset delay time is also included and internally set typically at 12ms (A/C version) or 50ms(B/D version).

FEATURES

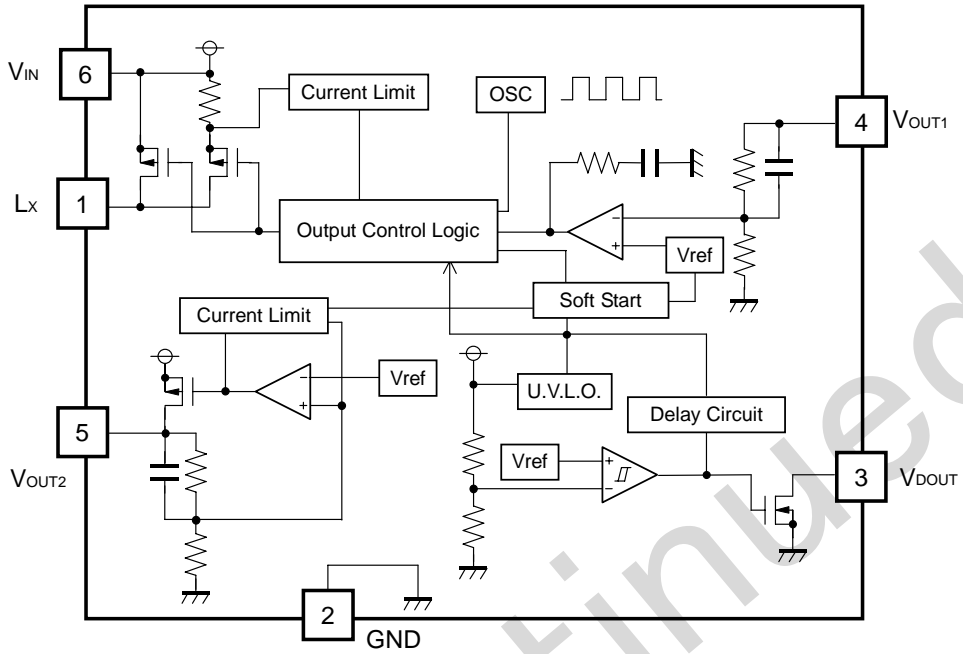
- Range of Input Voltage 3.0V~5.5V
- Built-in Soft-start Function (Typ. 1ms) and built-in power-on reset delay (Typ. 12ms or 50ms)
- Maximum Output Current.....500mA (DC/DC), 200mA (VR)
- Accuracy Output Voltage $\pm 2.0\%$ (DC/DC and Voltage Regulator Output)
- Accuracy of voltage detector..... $\pm 2.5\%$
- Output Voltage (VR)(A/B Version)..... Stepwise Setting with a step of 0.1V in the range of 2.0V to 3.6V
(C/D Version) Stepwise Setting with a step of 0.1V in the range of 1.2V to 3.0V
- Output Voltage (DC/DC) (A/B Version) Stepwise Setting with a step of 0.1V in the range of 1.2V to 3.6V
(C/D Version) Stepwise Setting with a step of 0.1V in the range of 2.5V to 3.6V
- Output Voltage (VD)..... Stepwise Setting with a step of 0.1V in the range of 3.0V to 4.5V
- Package HSON-6 (t=0.9mm)

APPLICATIONS

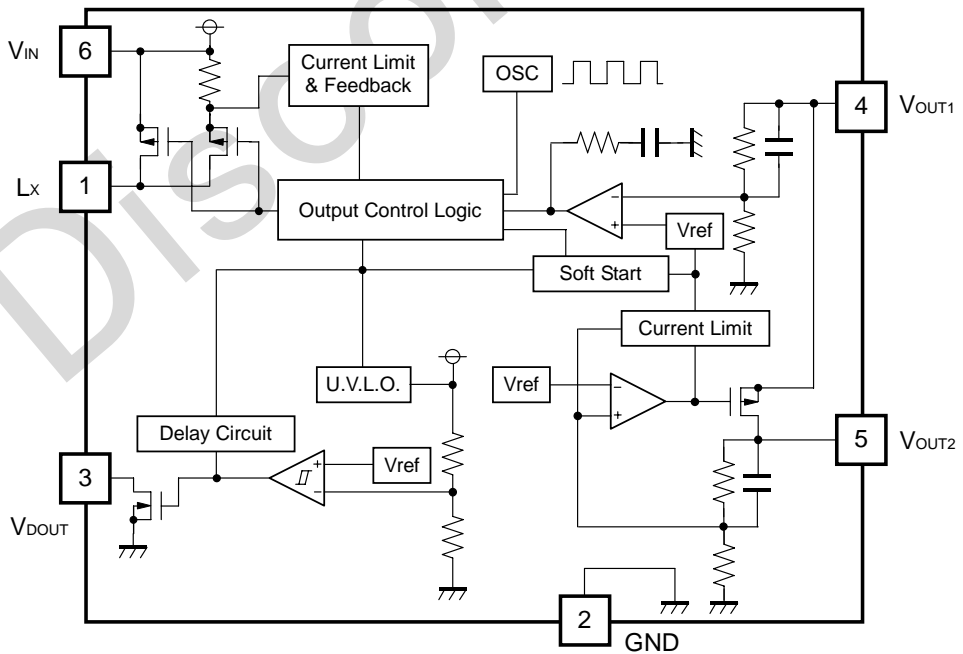
- Power source for hand-held communication equipment, CD or DVD drives.
- Power source for battery-powered equipment.

BLOCK DIAGRAMS

R5212xxxA/B



R5212DxxxC/D



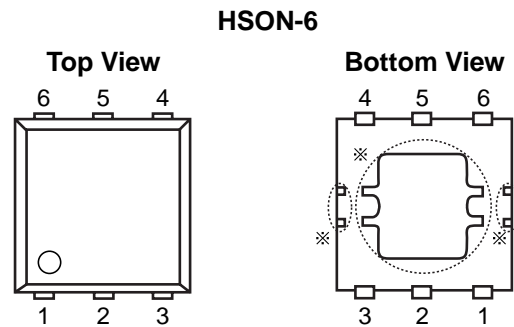
SELECTION GUIDE

In the R5212D Series, the output voltage combination for the ICs can be selected at the user's re-quest. The selection can be made with designating the part number as shown below;

R5212Dxxxx-TR ←Part Number
 ↑ ↑ ↑
 a b c

| Code | Contents |
|------|--|
| a | Output Voltage Combination Code Number |
| b | Designation of Optional Function A: VR input pin=V _{IN} pin, VD delay=12ms B: VR input pin=V _{IN} pin, VD delay=50ms C: VR input pin=DC/DC Output, VD delay=Typ. 12ms D: VR input pin=DC/DC Output, VD delay=Typ. 50ms |
| c | Designation of Taping Type: Refer to Taping specification. |

PIN CONFIGURATION



PIN DESCRIPTIONS

| Pin No | Symbol | Pin Description |
|--------|-------------------|--|
| 1 | L _X | Switching Pin (P-channel open-drain output type) |
| 2 | GND | Ground Pin |
| 3 | V _{DOUT} | Output Pin of Voltage Detector (N-channel open-drain out-put type) |
| 4 | V _{OUT1} | DC/DC converter Step-down Output monitoring Pin |
| 5 | V _{OUT2} | Output Pin of Voltage Regulator |
| 6 | V _{IN} | Voltage Supply Pin |

* Tab in the parts have GND level. (They are connected to the reverse side of this IC.)
Do not connect to other wires or land patterns.

ABSOLUTE MAXIMUM RATINGS

(GND=0V)

| Symbol | Item | Rating | Unit |
|-------------------|--|-----------------------------|------|
| V _{IN} | V _{IN} Pin Voltage | 6.5 | V |
| V _{LX} | L _X Pin Voltage | -0.3 ~ V _{IN} +0.3 | V |
| V _{OUT1} | V _{OUT1} Pin Voltage | -0.3 ~ V _{IN} +0.3 | V |
| V _{OUT2} | V _{OUT2} Pin Voltage | -0.3 ~ V _{IN} +0.3 | V |
| V _{DOUT} | V _{DOUT} Pin Voltage | -0.3 ~ 6.5 | V |
| I _{LX} | L _X Pin Output Current | 800 | mA |
| I _{OUT2} | V _{OUT2} Pin Output Current | 400 | mA |
| P _D | Power Dissipation (On Board) ^{*1} | 900 | mW |
| T _{opt} | Operating Temperature Range | -40 ~ +85 | °C |
| T _{stg} | Storage Temperature Range | -55 ~ +125 | °C |

*1) For Power Dissipation please refer to PACKAGE INFORMATION to be described.

ELECTRICAL CHARACTERISTICS

● R5212DxxxA

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|----------------------|--|--|------|------|------|------|
| V _{IN} | Operating Input Voltage | | 3.0 | | 5.5 | V |
| I _{DD} | Supply Current | V _{IN} =5.0V, V _{OUT1} =0V | | 400 | 800 | μA |
| V _{UVLO2} | UVLO Release Voltage | | 2.35 | 2.50 | 2.65 | V |
| V _{UVLOHYS} | UVLO Detector Threshold Voltage Hysteresis | | 0.05 | 0.15 | 0.25 | V |

● DC/DC Part

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|----------------------------|------|----------------------------|------------|
| V _{OUT1} | DC/DC Output Voltage | V _{IN} =5.0V, at no load OPEN LOOP | V _{OUT1} ×0.98 | | V _{OUT1} ×1.02 | V |
| ΔV _{OUT1} / ΔT _{opt} | DC/DC Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| f _{OSC} | Oscillator Frequency | V _{IN} =5.0V | 960 | 1200 | 1440 | kHz |
| R _{LX} | Lx on Resistance | V _{IN} =5.0V, I _{LX} =100mA | | 0.4 | 0.8 | Ω |
| I _{LXleak} | Lx Leakage Current | V _{IN} =V _{OUT1} =5.5V, V _{LX} =0V | | 0.01 | 5.00 | μA |
| I _{LXLIM} | Lx Current Limit | V _{IN} =5.0V | 600 | 800 | | mA |
| Maxduty | Maximum duty cycle | | 100 | | | % |
| t _{start} | Soft-start Time | V _{IN} =5.0V | 0.35 | 1.00 | 3.00 | ms |

● VR Part

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|--|--|----------------------------|------|----------------------------|------------|
| V _{OUT2} | VR Output Voltage | V _{IN} =5.0V, I _{OUT2} =10mA | V _{OUT2} ×0.98 | | V _{OUT2} ×1.02 | V |
| I _{OUT2} | Maximum Output Current of VR | V _{IN} =5.0V | 200 | | | mA |
| V _{REG2} | VR Load Regulation | V _{IN} -V _{OUT2} =0V 1mA ≤ I _{OUT2} ≤ 80mA | | 20 | 60 | mV |
| V _{DIF2} | Dropout Voltage | I _{OUT2} =100mA | | 0.2 | 0.3 | V |
| I _{LIM2} | Short Current Limit | V _{OUT2} =0V | | 50 | | mA |
| ΔV _{OUT2} / ΔT _{opt} | VR Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |

● VD Part

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|--|---|-----------------------------|----------------------------|-----------------------------|------------|
| -V _{DET} | VD Detector Threshold | | -V _{DET} ×0.975 | | -V _{DET} ×1.025 | V |
| Δ-V _{DET} / ΔT _{opt} | VD Detector Threshold Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| V _{HYS} | Hysteresis Range | | | -V _{DET} ×0.05 | | V |
| t _{PLH} | VD Output Delay Time for Release | V _{IN} =V _{DOUT} =-V _{DET} ×0.9 to 5.0 | 3 | 12 | 30 | ms |
| I _{DOUTL} | V _{DOUT} "L" Output Current | V _{IN} =2.0V, I _{OUT} =0.1V | 2 | 7 | 20 | mA |

R5212D**Discontinued**● **R5212DxxxB**T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|----------------------|--|--|------|------|------|------|
| V _{IN} | Operating Input Voltage | | 3.0 | | 5.5 | V |
| I _{DD} | Supply Current | V _{IN} =5.0V, V _{OUT1} =0V | | 400 | 800 | μA |
| V _{UVLO2} | UVLO Release Voltage | | 2.35 | 2.50 | 2.65 | V |
| V _{UVLOHYS} | UVLO Detector Threshold Voltage Hysteresis | | 0.05 | 0.15 | 0.25 | V |

● **DC/DC Part**T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|--|---|----------------------------|------|----------------------------|------------|
| V _{OUT1} | DC/DC Output Voltage | V _{IN} =5.0V, at no load OPEN LOOP | V _{OUT1} ×0.98 | | V _{OUT1} ×1.02 | V |
| ΔV _{OUT1} / ΔT _{opt} | DC/DC Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| f _{osc} | Oscillator Frequency | V _{IN} =5.0V | 960 | 1200 | 1440 | kHz |
| R _{LX} | Lx on Resistance | V _{IN} =5.0V, I _{LX} =100mA | | 0.4 | 0.8 | Ω |
| I _{LXleak} | Lx Leakage Current | V _{IN} =V _{OUT1} =5.5V, V _{LX} =0V | | 0.01 | 5.00 | μA |
| I _{LXLIM} | Lx Current Limit | V _{IN} =5.0V | 600 | 850 | | mA |
| Maxduty | Maximum duty cycle | | 100 | | | % |
| t _{start} | Soft-start Time | V _{IN} =5.0V | 0.35 | 1.00 | 3.00 | ms |

● **VR Part**T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|--|----------------------------|------|----------------------------|------------|
| V _{OUT2} | VR Output Voltage | V _{IN} =5.0V, I _{OUT2} =10mA | V _{OUT2} ×0.98 | | V _{OUT2} ×1.02 | V |
| I _{OUT2} | Maximum Output Current of VR | V _{IN} =5.0V | 200 | | | mA |
| V _{REG2} | VR Load Regulation | V _{IN} -V _{OUT2} =0V 1mA ≤ I _{OUT2} ≤ 80mA | | 20 | 60 | mV |
| V _{DIF2} | Dropout Voltage | I _{OUT2} =100mA | | 0.2 | 0.3 | V |
| I _{LIM2} | Short Current Limit | V _{OUT2} =0V | | 50 | | mA |
| ΔV _{OUT2} / ΔT _{opt} | VR Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |

● **VD Part**T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|-----------------------------|----------------------------|-----------------------------|------------|
| -V _{DET} | VD Detector Threshold | | -V _{DET} ×0.975 | | -V _{DET} ×1.025 | V |
| Δ-V _{DET} / ΔT _{opt} | VD Detector Threshold Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| V _{HYS} | Hysteresis Range | | | -V _{DET} ×0.05 | | V |
| t _{PLH} | VD Output Delay Time for Release | V _{IN} =V _{DOUT} =-V _{DET} ×0.9 to 5.0 | 3 | 12 | 30 | ms |
| I _{DOUTL} | V _{DOUT} "L" Output Current | V _{IN} =2.0V, V _{DOUT} =0.1V | 2 | 7 | 20 | mA |

● R5212DxxxC

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|----------------------|--|--|------|------|------|------|
| V _{IN} | Operating Input Voltage | | 3.0 | | 5.5 | V |
| I _{DD} | Supply Current | V _{IN} =5.0V, V _{OUT1} =0V | | 400 | 800 | μA |
| V _{UVLO2} | UVLO Release Voltage | | 2.35 | 2.50 | 2.65 | V |
| V _{UVLOHYS} | UVLO Detector Threshold Voltage Hysteresis | | 0.05 | 0.15 | 0.25 | V |

● DC/DC Part

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|--|---|----------------------------|------|----------------------------|------------|
| V _{OUT1} | DC/DC Output Voltage | V _{IN} =5.0V, at no load OPEN LOOP | V _{OUT1} ×0.98 | | V _{OUT1} ×1.02 | V |
| ΔV _{OUT1} / ΔT _{opt} | DC/DC Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| f _{osc} | Oscillator Frequency | V _{IN} =5.0V | 960 | 1200 | 1440 | kHz |
| R _{LX} | Lx on Resistance | V _{IN} =5.0V, I _{LX} =100mA | | 0.4 | 0.8 | Ω |
| I _{LXleak} | Lx Leakage Current | V _{IN} =V _{OUT1} =5.5V, V _{LX} =0V | | 0.01 | 5.00 | μA |
| I _{LXLIM} | Lx Current Limit | V _{IN} =5.0V | 600 | 850 | | mA |
| Maxduty | Maximum duty cycle | | 100 | | | % |
| t _{start} | Soft-start Time | V _{IN} =5.0V | 0.35 | 1.00 | 3.00 | ms |

● VR Part

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|--|----------------------------|------|----------------------------|------------|
| V _{OUT2} | VR Output Voltage | V _{OUT1} =3.3V I _{OUT2} =10mA | V _{OUT2} ×0.98 | | V _{OUT2} ×1.02 | V |
| I _{OUT2} | Maximum Output Current of VR | V _{IN} =5.0V | 200 | | | mA |
| V _{REG2} | VR Load Regulation | V _{IN} -V _{OUT2} =0V 1mA ≤ I _{OUT2} ≤ 80mA | | 20 | 60 | mV |
| V _{DIF2} | Dropout Voltage | I _{OUT2} =100mA | | 0.2 | 0.3 | V |
| I _{LIM2} | Short Current Limit | V _{OUT2} =0V | | 50 | | mA |
| ΔV _{OUT2} / ΔT _{opt} | VR Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |

● VD Part

T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|-----------------------------|----------------------------|-----------------------------|------------|
| -V _{DET} | VD Detector Threshold | | -V _{DET} ×0.975 | | -V _{DET} ×1.025 | V |
| Δ-V _{DET} / ΔT _{opt} | VD Detector Threshold Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| V _{HYS} | Hysteresis Range | | | -V _{DET} ×0.05 | | V |
| t _{PLH} | VD Output Delay Time for Release | V _{IN} =V _{DOUT} =-V _{DET} ×0.9 to 5.0 | 3 | 12 | 30 | ms |
| I _{DOUTL} | V _{DOUT} "L" Output Current | V _{IN} =2.0V, V _{DOUT} =0.1V | 2 | 7 | 20 | mA |

R5212D**Discontinued**● **R5212DxxxD**T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|----------------------|--|--|------|------|------|------|
| V _{IN} | Operating Input Voltage | | 3.0 | | 5.5 | V |
| I _{DD} | Supply Current | V _{IN} =5.0V, V _{OUT1} =0V | | 400 | 800 | μA |
| V _{UVLO2} | UVLO Release Voltage | | 2.35 | 2.50 | 2.65 | V |
| V _{UVLOHYS} | UVLO Detector Threshold Voltage Hysteresis | | 0.05 | 0.15 | 0.25 | V |

● **DC/DC Part**T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|--|---|----------------------------|------|----------------------------|------------|
| V _{OUT1} | DC/DC Output Voltage | V _{IN} =5.0V, at no load OPEN LOOP | V _{OUT1} ×0.98 | | V _{OUT1} ×1.02 | V |
| ΔV _{OUT1} / ΔT _{opt} | DC/DC Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| f _{osc} | Oscillator Frequency | V _{IN} =5.0V | 960 | 1200 | 1440 | kHz |
| R _{LX} | Lx on Resistance | V _{IN} =5.0V, I _{LX} =100mA | | 0.4 | 0.8 | Ω |
| I _{LXleak} | Lx Leakage Current | V _{IN} =V _{OUT1} =5.5V, V _{LX} =0V | | 0.01 | 5.00 | μA |
| I _{LXLIM} | Lx Current Limit | V _{IN} =5.0V | 600 | 850 | | mA |
| Maxduty | Maximum duty cycle | | 100 | | | % |
| t _{start} | Soft-start Time | V _{IN} =5.0V | 0.35 | 1.00 | 3.00 | ms |

● **VR Part**T_{opt}=25°C

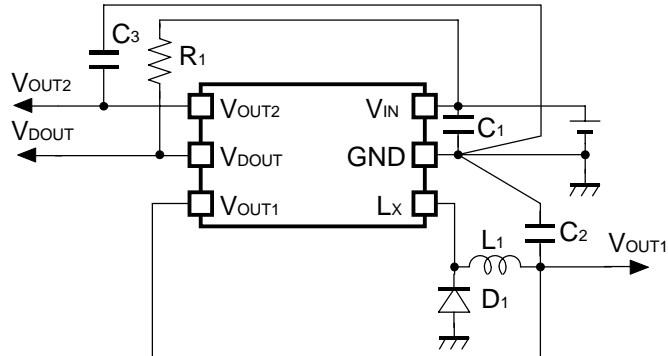
| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|--|----------------------------|------|----------------------------|------------|
| V _{OUT2} | VR Output Voltage | V _{OUT1} =3.3V I _{OUT2} =10mA | V _{OUT2} ×0.98 | | V _{OUT2} ×1.02 | V |
| I _{OUT2} | Maximum Output Current of VR | V _{IN} =5.0V, V _{OUT1} =3.3V | 200 | | | mA |
| V _{REG2} | VR Load Regulation | V _{IN} -V _{OUT2} =0V 1mA ≤ I _{OUT2} ≤ 80mA | | 20 | 60 | mV |
| V _{DIF2} | Dropout Voltage | I _{OUT2} =100mA | | 0.2 | 0.3 | V |
| I _{LIM2} | Short Current Limit | V _{OUT2} =0V | | 50 | | mA |
| ΔV _{OUT2} / ΔT _{opt} | VR Output Voltage Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |

● **VD Part**T_{opt}=25°C

| Symbol | Item | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|-----------------------------|----------------------------|-----------------------------|------------|
| -V _{DET} | VD Detector Threshold | | -V _{DET} ×0.975 | | -V _{DET} ×1.025 | V |
| Δ-V _{DET} / ΔT _{opt} | VD Detector Threshold Temperature Coefficient | 40°C ≤ T _{opt} ≤ 85°C | | ±100 | | ppm /°C |
| V _{HYS} | Hysteresis Range | | | -V _{DET} ×0.05 | | V |
| t _{PLH} | VD Output Delay Time for Release | V _{IN} =V _{DOUT} =-V _{DET} ×0.9 to 5.0 | 10 | 50 | 120 | ms |
| I _{DOUTL} | V _{DOUT} "L" Output Current | V _{IN} =2.0V, V _{DOUT} =0.1V | 2 | 7 | 20 | mA |

TYPICAL APPLICATION AND APPLICATION HINTS

R5212Dxxxx



Examples of Components

| Symbol | Item | | | |
|----------------|---------------------------------------|-------|----------------|--------|
| L ₁ | (V _{OUT1} ≤ 1.6V) | 4.7μH | LQH43C Series | Murata |
| | | 4.7μH | VLP5610 Series | TDK |
| | (V _{OUT1} > 1.6V) | 6.8μH | LQH43C Series | Murata |
| | | 6.8μH | VLP5610 Series | TDK |
| D ₁ | RB491D(ROHM) or EP05Q03 (Nihon Inter) | | | |
| R ₁ | 50kΩ | | | |
| C ₁ | 10μF Ceramic Capacitor | | | |
| C ₂ | 10μF Ceramic Capacitor | | | |
| C ₃ | 2.2μF Ceramic Capacitor | | | |

R5212D**Discontinued**

When you use these ICs, consider the following issues;

Set external components as close as possible to the IC and minimize the connection between the components and the IC. In particular, a capacitor should be connected to between V_{IN} and GND with the minimum connection. Make sufficient grounding, and reinforce supplying. A large switching current may flow through the connection of power supply, an inductor and the connection of V_{OUT1} . If the impedance of the connection of power supply or ground is high, the voltage level of power supply of the IC fluctuates with the switching current. This may cause unstable operation of the IC.

Use a capacitor with a capacity of $10\mu\text{F}$ or more for V_{IN} and GND, and with low ESR ceramic type. In terms of V_{OUT1} , use a ceramic capacitor with a capacity of $10\mu\text{F}$ or more. For V_{OUT2} pin, use a ceramic capacitor with a capacitance of $2.2\mu\text{F}$ or around.

Choose an inductor that has a small D.C. resistance and large allowable current and which is hard to reach magnetic saturation. If the value of inductance of an inductor is extremely small, the I_{Lx} , which flows through Lx transistor and an inductor, may exceed the absolute maximum rating at the maximum loading.

Use an inductor with appropriate inductance.

Use a diode of a Schottky type with high switching speed, and also pay attention to its current capacity.

If the spike noise of Lx pin is too large, make snub circuit (such as serial connection of CR) between Lx and GND, then the noise will be reduced. The time constant of the CR depends on the actual PCB, so evaluate it on the actual PCB.

If the load current of the voltage regulator is small, because of the switching noise of DC/DC converter, the output voltage of V_{OUT2} may be large. To avoid this, use the voltage regulator with a load current at least 0.5mA .

In terms of LDO, the difference between the set output voltage and input voltage should be 0.5V or more,

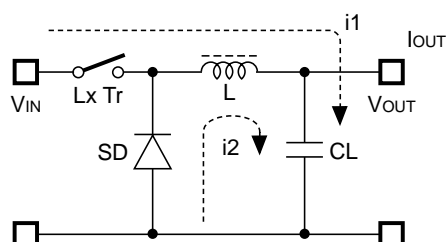
The performance of power source circuits using these ICs extremely depends upon the peripheral circuits.

Pay attention in the selection of the peripheral circuits. In particular, design the peripheral circuits in a way that the values such as voltage, current, and power of each component, PCB patterns and the IC do not exceed their respected rated values.

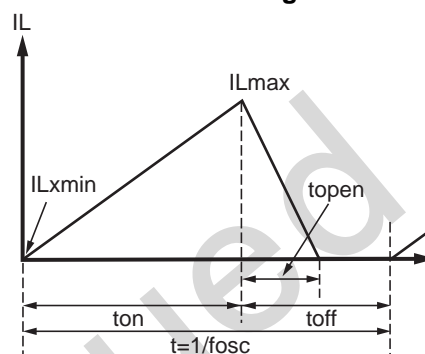
OPERATION of step-down DC/DC converter and Output Current

The step-down DC/DC converter charges energy in the inductor when Lx transistor is ON, and discharges the energy from the inductor when Lx transistor is OFF and controls with less energy loss, so that a lower output voltage than the input voltage is obtained. The operation will be explained with reference to the following diagrams:

<Basic Circuits>



<Current through L>



- Step 1 : Lx Tr. turns on and current $I_L (=i1)$ flows, and energy is charged into CL. At this moment, I_L increases from $I_{Lmin} (=0)$ to reach I_{Lmax} in proportion to the on-time period (t_{on}) of Lx Tr.
- Step 2 : When Lx Tr. turns off, Schottky diode (SD) turns on in order that L maintains I_L at I_{Lmax} , and current $I_L (=i2)$ flows.
- Step 3 : I_L decreases gradually and reaches I_{Lmin} after a time period of t_{open} , and SD turns off, provided that in the continuous mode, next cycle starts before I_L becomes to 0 because t_{off} time is not enough. In this case, I_L value is from this $I_{Lmin} (>0)$.

In the case of PWM control system, the output voltage is maintained by controlling the on-time period (t_{on}), with the oscillator frequency (f_{osc}) being maintained constant.

• Discontinuous Conduction Mode and Continuous Conduction Mode

The maximum value (I_{Lmax}) and the minimum value (I_{Lmin}) current which flow through the inductor is the same as those when $Lx Tr.$ turns on and when it turns off.

The difference between I_{Lmax} and I_{Lmin} , which is represented by ΔI ;

$$\Delta I = I_{Lmax} - I_{Lmin} = V_{OUT} \times t_{open} / L = (V_{IN} - V_{OUT}) \times t_{on} / L \dots\dots\dots \text{Equation 1}$$

Where, $t = 1 / f_{osc} = t_{on} + t_{off}$
duty (%) = $t_{on} / t \times 100 = t_{on} \times f_{osc} \times 100$
 $t_{open} \leq t_{off}$

In Equation A, $V_{OUT} \times t_{open} / L$ and $(V_{IN} - V_{OUT}) \times t_{on} / L$ are respectively shown the change of the current at ON, and the change of the current at OFF.

When the output current (I_{OUT}) is relatively small, $t_{open} < t_{off}$ as illustrated in the above diagram. In this case, the energy is charged in the inductor during the time period of t_{on} and is discharged in its entirety during the time period of t_{off} , therefore I_{Lmin} becomes to zero ($I_{Lmin} = 0$). When I_{OUT} is gradually increased, eventually, t_{open} becomes to t_{off} ($t_{open} = t_{off}$), and when I_{OUT} is further increased, I_{Lmin} becomes larger than zero ($I_{Lmin} > 0$). The former mode is referred to as the discontinuous mode and the latter mode is referred to as continuous mode.

In the continuous mode, when Equation 1 is solved for t_{on} and assumed that the solution is t_{onc}

$$t_{onc} = t \times V_{OUT} / V_{IN} \dots\dots\dots \text{Equation 2}$$

When $t_{on} < t_{onc}$, the mode is the discontinuous mode, and when $t_{on} = t_{onc}$, the mode is the continuous mode.

OUTPUT CURRENT AND SELECTION OF EXTERNAL COMPONENTS

When $Lx Tr.$ is "ON":

(Wherein, Ripple Current P-P value is described as I_{RP} , ON resistance of $Lx Tr.$ is described as R_P the direct current of the inductor is described as R_L . The threshold level of Shottky diode is described as V_F .)

$$V_{IN} = V_{OUT} + (R_P + R_L) \times I_{OUT} + L \times I_{RP} / t_{on} \dots\dots\dots \text{Equation 3}$$

When $Lx Tr.$ is "OFF":

$$L \times I_{RP} / t_{off} = V_F + V_{OUT} + R_L \times I_{OUT} \dots\dots\dots \text{Equation 4}$$

Put Equation 4 to Equation 3 and solve for ON duty, $t_{on} / (t_{off} + t_{on}) = D_{ON}$,

$$D_{ON} = (V_{OUT} + V_F + R_L \times I_{OUT}) / (V_{IN} + V_F - R_P \times I_{OUT}) \dots\dots\dots \text{Equation 5}$$

Ripple Current is as follows;

$$I_{RP} = (V_{IN} - V_{OUT} - R_P \times I_{OUT} - R_L \times I_{OUT}) \times D_{ON} / f / L \dots\dots\dots \text{Equation 6}$$

Wherein, peak current that flows through L , $Lx Tr.$, and SD is as follows;

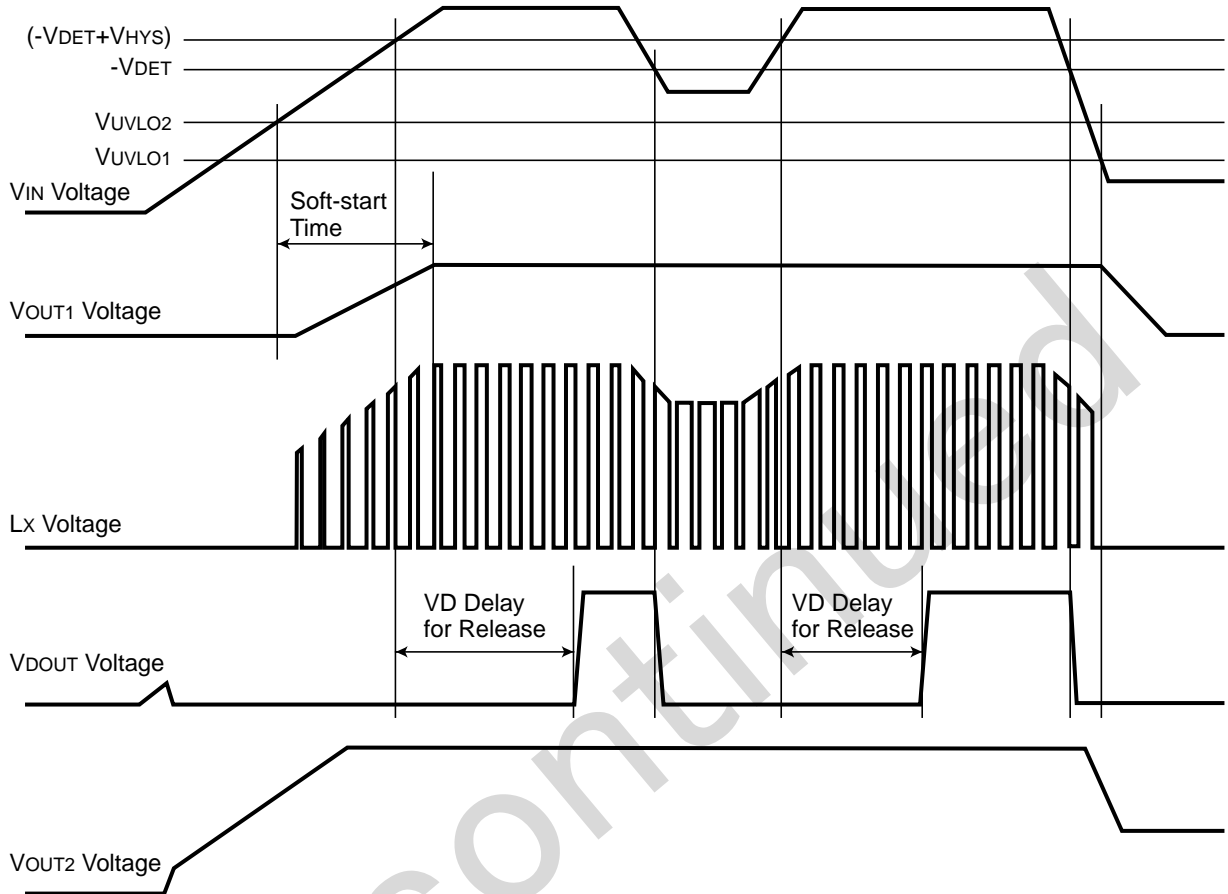
$$I_{Lmax} = I_{OUT} + I_{RP} / 2 \dots\dots\dots \text{Equation 7}$$

Consider I_{Lmax} , condition of input and output and select external components.

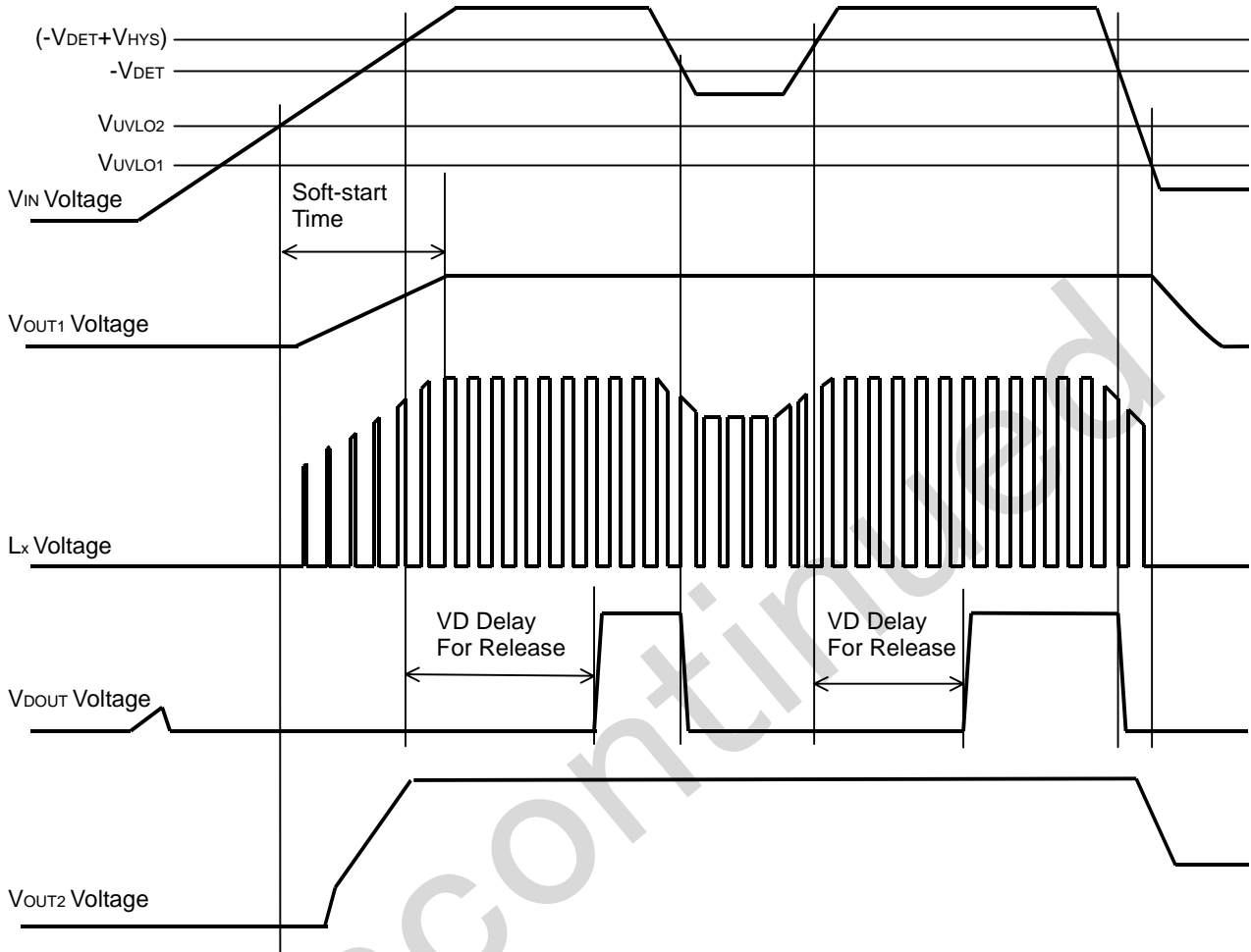
★The above explanation is directed to the calculation in an ideal case in continuous mode.

Timing Chart

• R5212DxxxA/B



• R5212DxxxC/D



The timing chart which is shown in the previous page describes the relation of supply voltage changes with time and each output of DC/DC converter, voltage detector, and voltage regulator.

(1) DC/DC converter

When the power turns on and in the case of rising the V_{IN} voltage, while the V_{IN} voltage is at UVLO release level (V_{UVLO2}) or less, the operation of the DC/DC converter stops and does not make switching, therefore V_{OUT1} voltage does not rise.

When the V_{IN} voltage becomes UVLO release level or more, the DC/DC converter starts soft-start operation, and start switching, then V_{OUT1} will rise. After the soft-start time, if V_{IN} voltage becomes set V_{OUT1} level or more, V_{OUT1} will be settled at V_{OUT1} set output voltage. If V_{IN} voltage becomes UVLO detector threshold level (V_{UVLO1}) or less, the DC/DC converter stops switching then L_x transistor in the IC turns off.

(2) Voltage Detector

If the V_{IN} voltage is at VD detector threshold level or less, the N-channel transistor of V_{DDOUT} pin turns on and outputs "L" to V_{DDOUT} pin. Then, when the V_{IN} voltage becomes VD detector threshold level + its hysteresis range ($-V_{DET}+V_{HYS}$) or more, after VD delay for release (t_{PLH}) passing, the N-channel transistor inside the IC turns off, V_{DDOUT} pin voltage reaches to the pull-up voltage. Besides, the release circuit for VD starts from when V_{IN} voltage reaches ($-V_{DET}+V_{HYS}$).

(3)Voltage Regulator

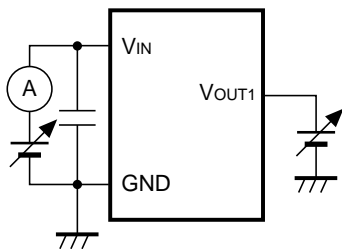
• **R5212DxxxA/B**

The voltage regulator always operates even if UVLO function would work. Therefore, V_{OUT2} voltage is nearly equal to V_{IN} voltage. Actual value depends on the load current. When the V_{IN} voltage becomes set V_{OUT2} voltage or more, V_{OUT2} voltage will be the set output voltage. The short current limit can operate after soft-start time.

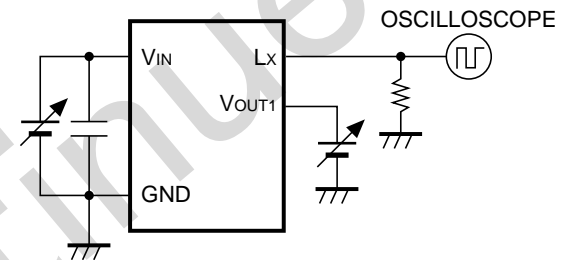
• **R5212DxxxC/D**

V_{OUT1} voltage is the input voltage for the built-in LDO, when the V_{OUT1} voltage is equal or less than V_{OUT2} set voltage, V_{OUT2} voltage is depending on the load current for V_{OUT2} , however almost same as V_{OUT1} Voltage. When the V_{OUT1} voltage is equal or more than set V_{OUT2} voltage, V_{OUT2} voltage becomes the set output voltage. Short Current Limit works after soft-start operation.

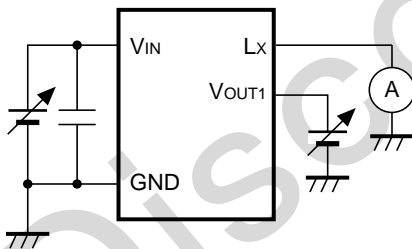
TEST CIRCUITS



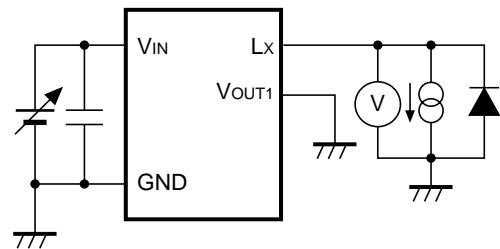
Supply Current



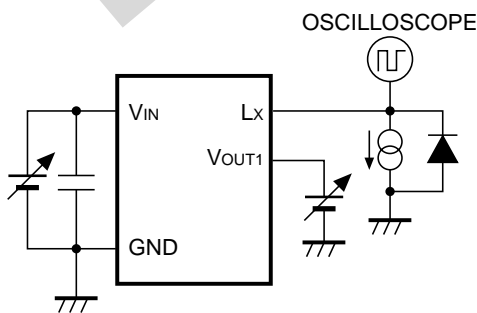
UVLO Detector Threshold/ Released Voltage



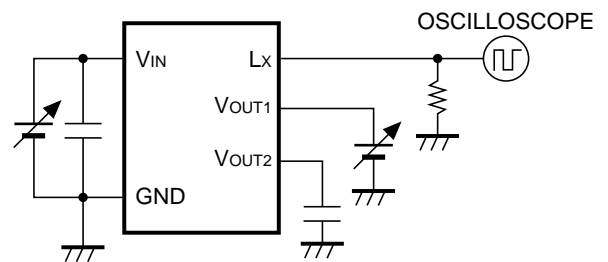
Lx Leakage Current



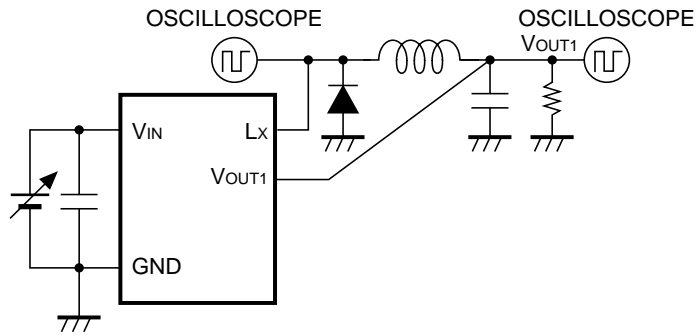
Lx On Resistance



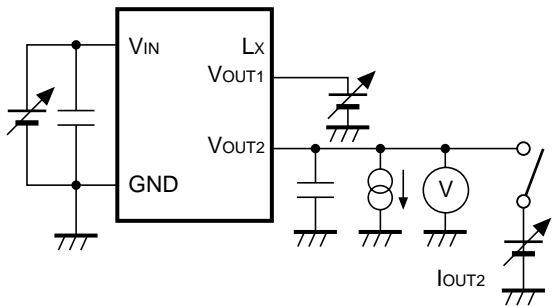
Lx Current Limit



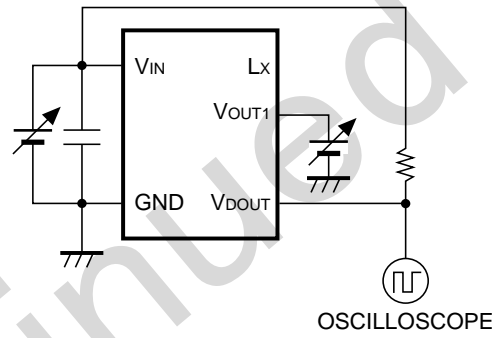
V_{OUT1} Output Voltage



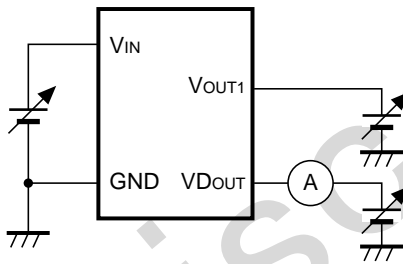
Oscillator Frequency, Soft-start Time



V_{OUT2} Output Voltage, Load Regulation, Dropout Voltage, Current Limit, Short Current Limit



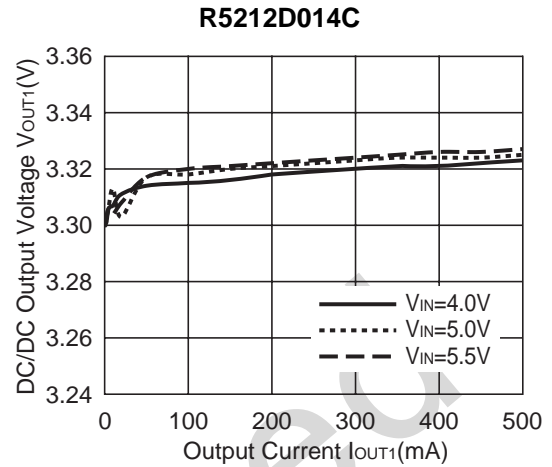
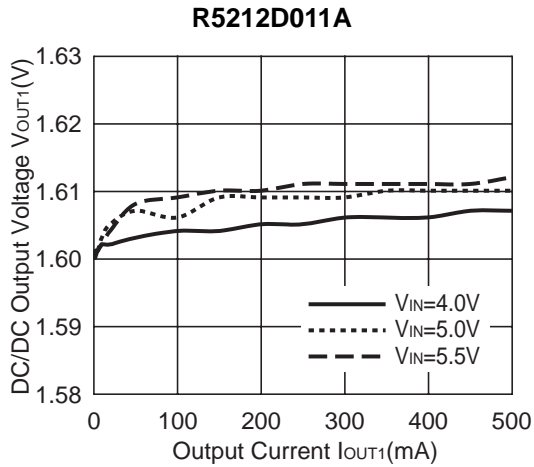
V_{DOUT} Detector Threshold, Hysteresis Range, VD Output Delay Time for Release



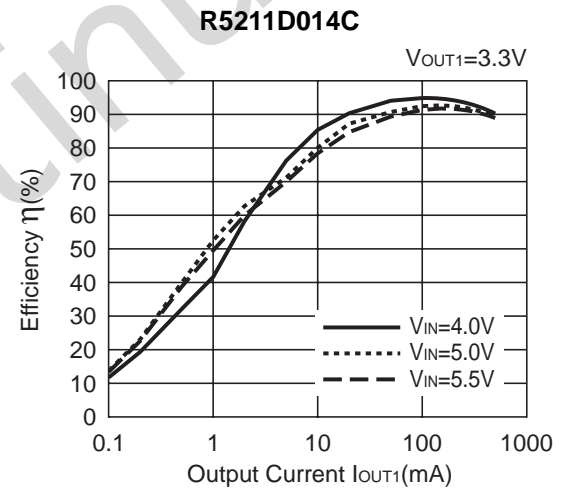
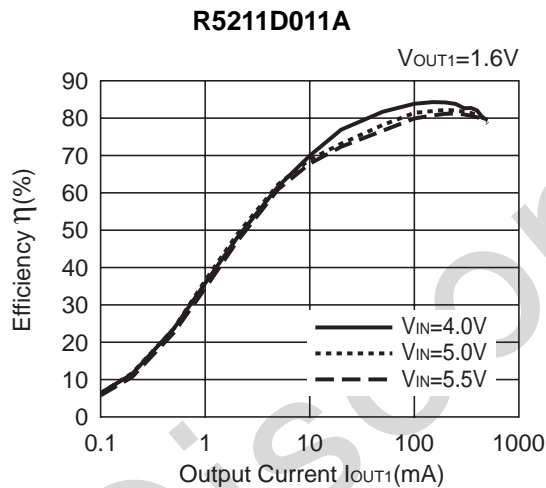
V_{DOUT} "L" Output Current

TYPICAL CHARACTERISTICS

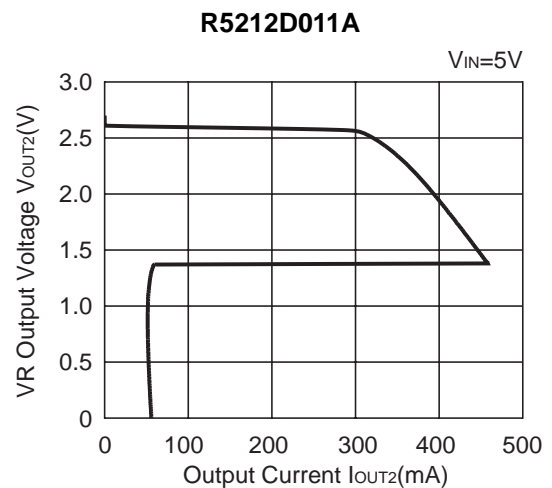
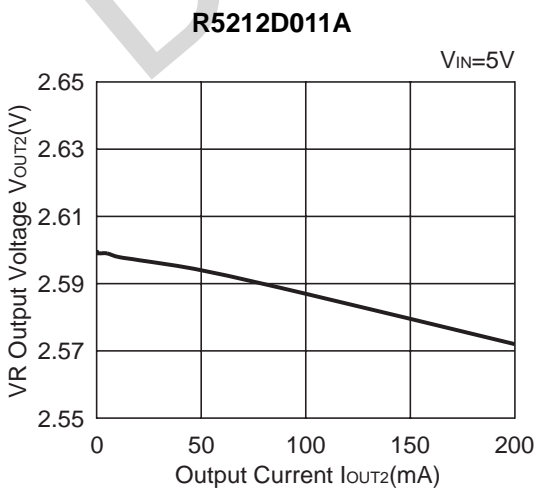
1) DC/DC Output Voltage vs. Output Current (Topt=25°C)



2) Efficiency vs. Output Current (Topt=25°C)

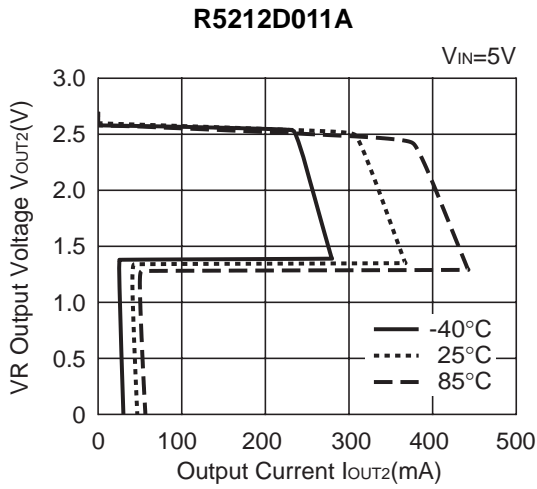


3) VR Output Voltage vs. Output Current (Topt=25°C)

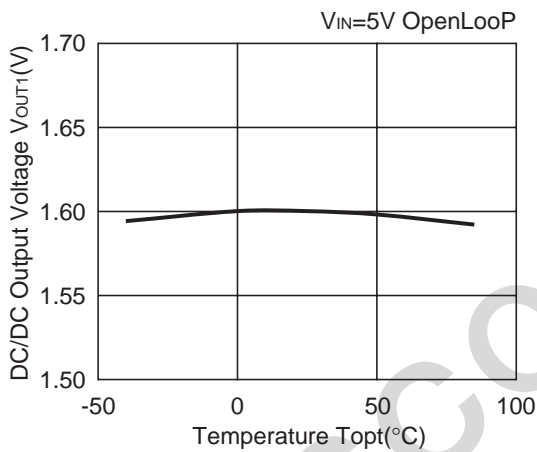


R5212D

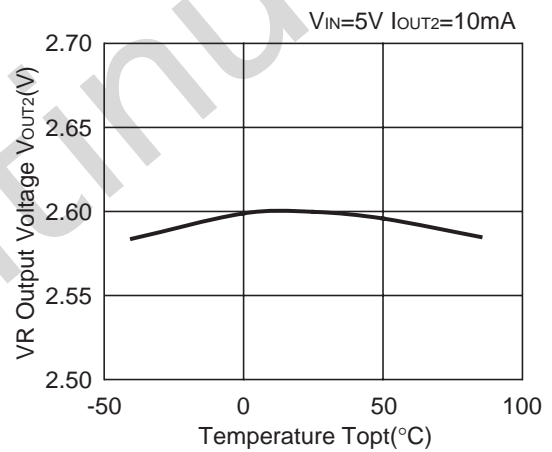
Discontinued



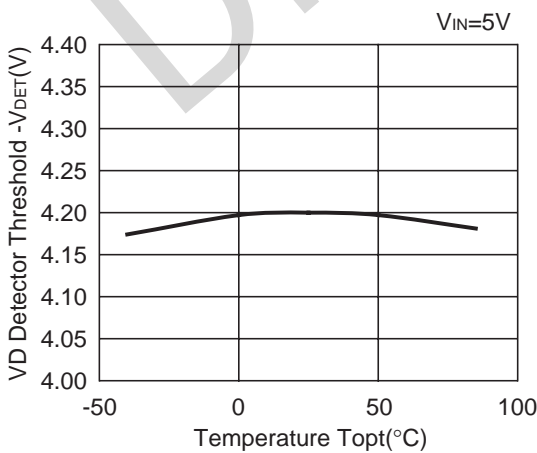
4) DC/DC Output Voltage vs. Temperature
R5212D011A



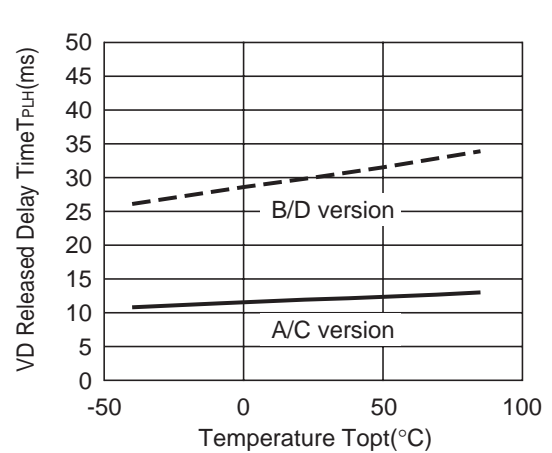
5) VR Output Voltage vs. Temperature
R5212D011A



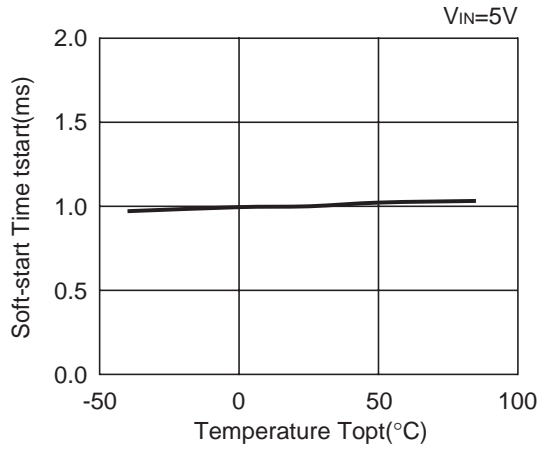
6) VD Detector Threshold vs. Temperature
R5212D011A



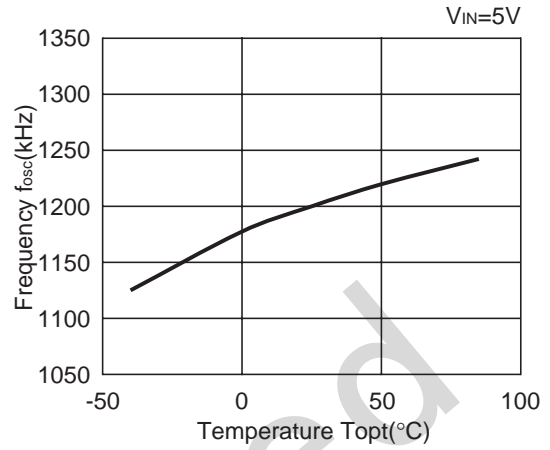
7) VD Released Delay Time vs. Temperature
R5212D



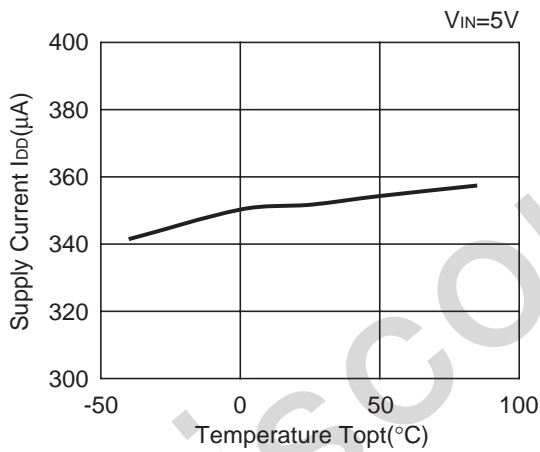
8) Soft-start time vs. Temperature
R5212D011A



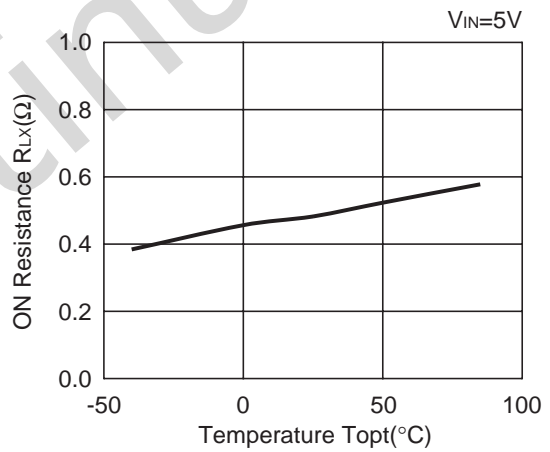
9) Frequency vs. Temperature
R5212D011A



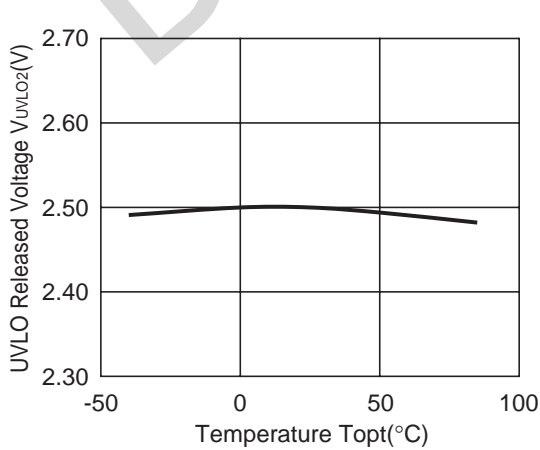
10) Supply Current vs. Temperature
R5212D011A



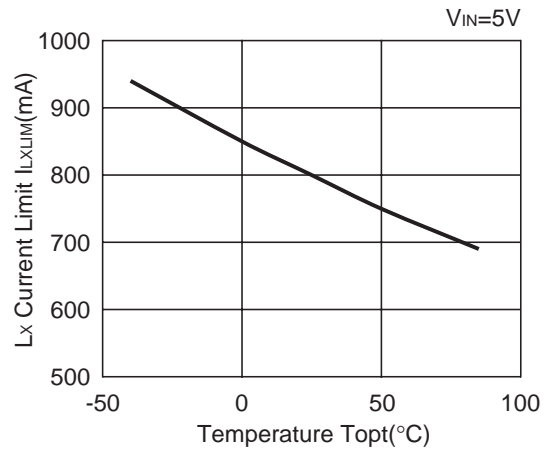
11) ON Resistance vs. Temperature
R5212D011A



12) UVLO Released Voltage vs. Temperature
R5212D011A

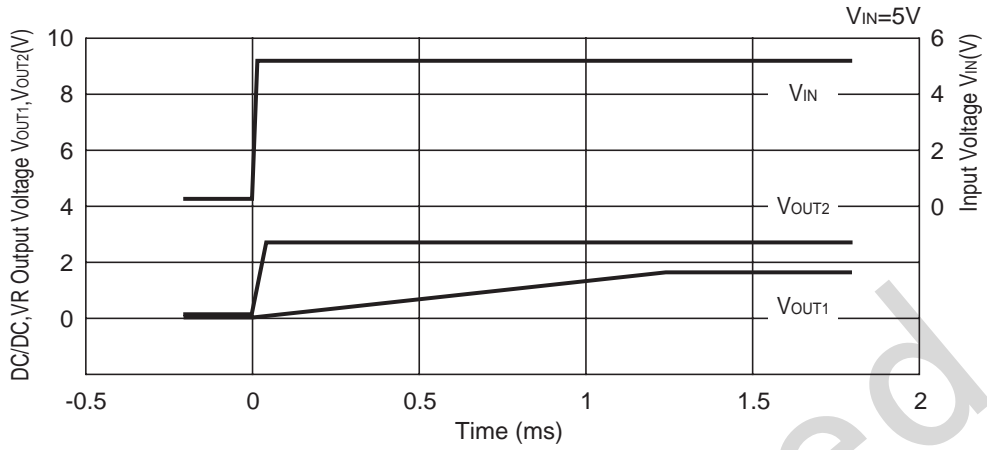


13) Lx Current Limit vs. Temperature
R5212D011A



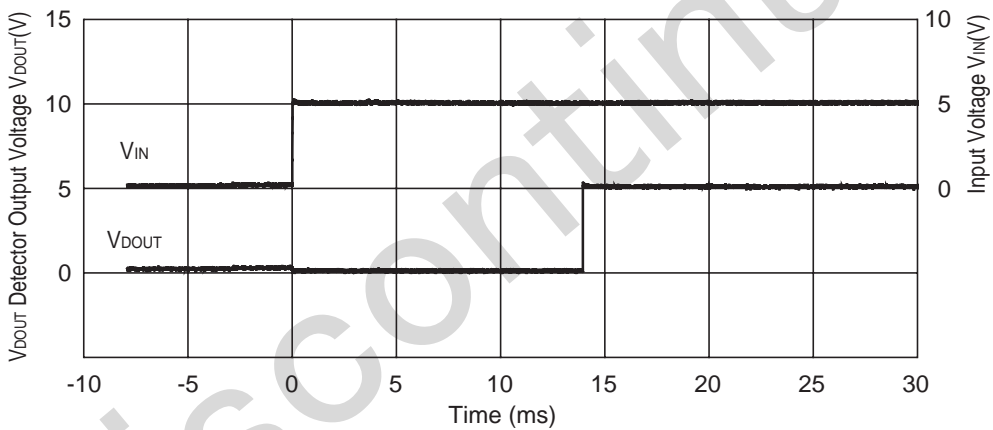
14) Soft-start Output Waveform (T_{opt}=25°C)

R5212D011A



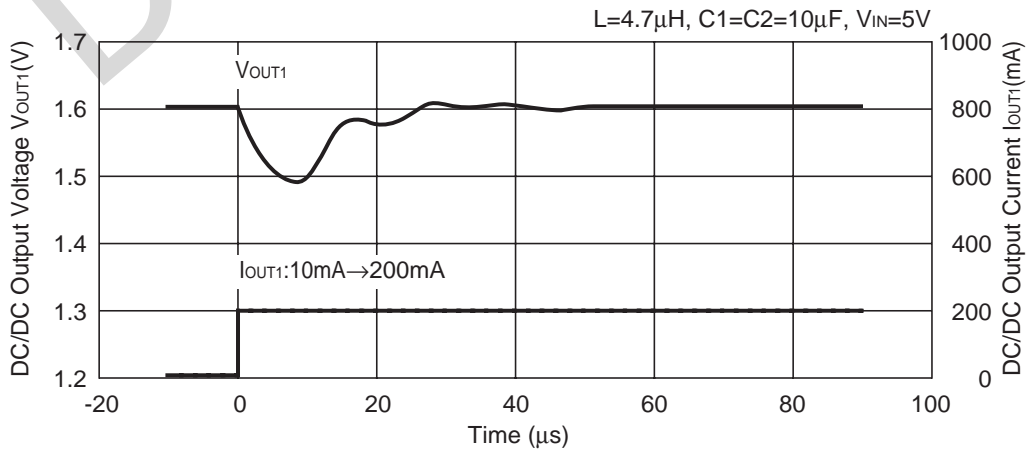
15) VD Released Delay Waveform (T_{opt}=25°C)

R5212D011A

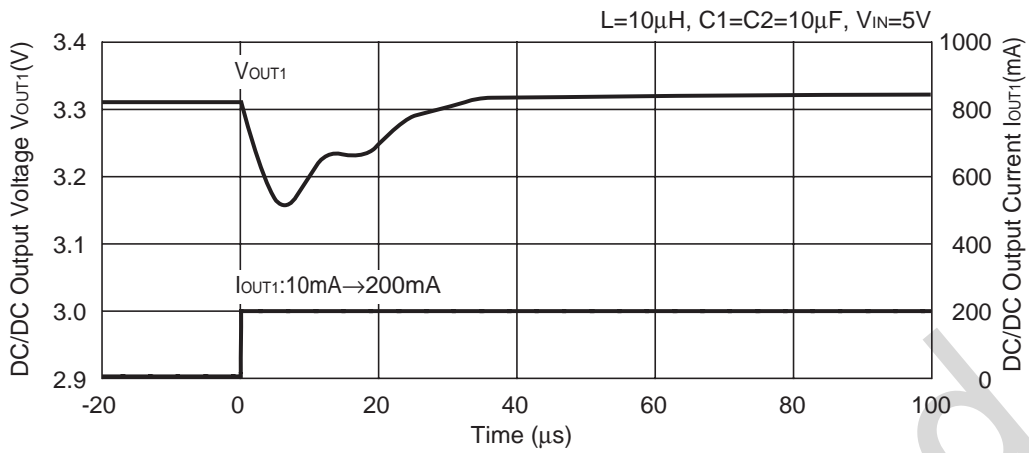


16) DC/DC Load Transient Response 1 (T_{opt}=25°C)

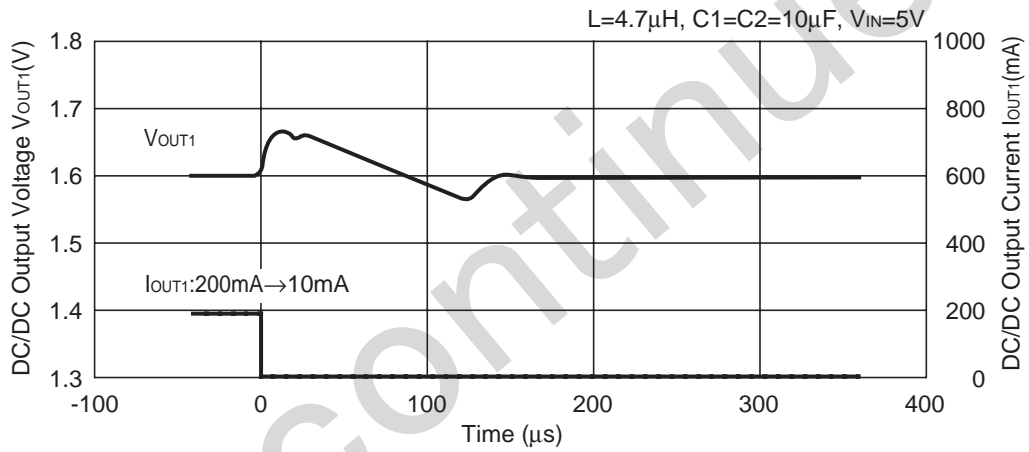
R5212D011A



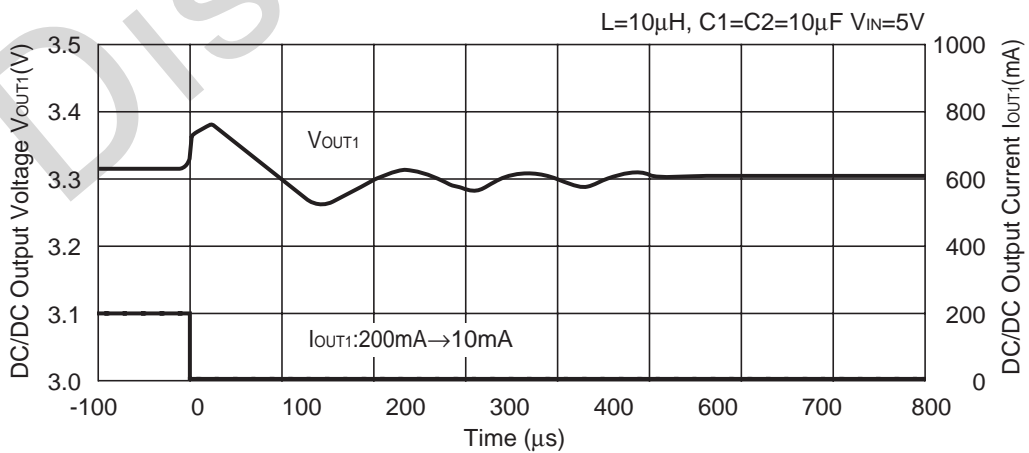
R5212D014C



R5212D011A



R5212D014C

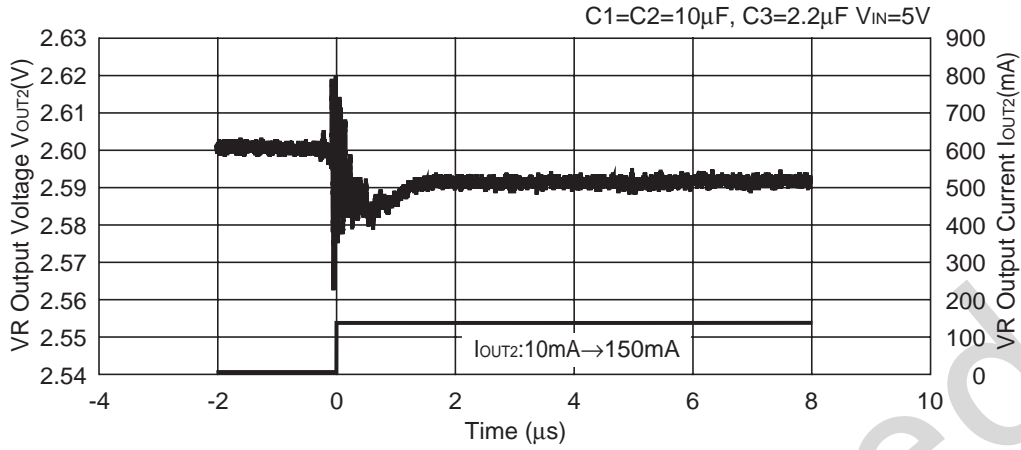


R5212D

Discontinued

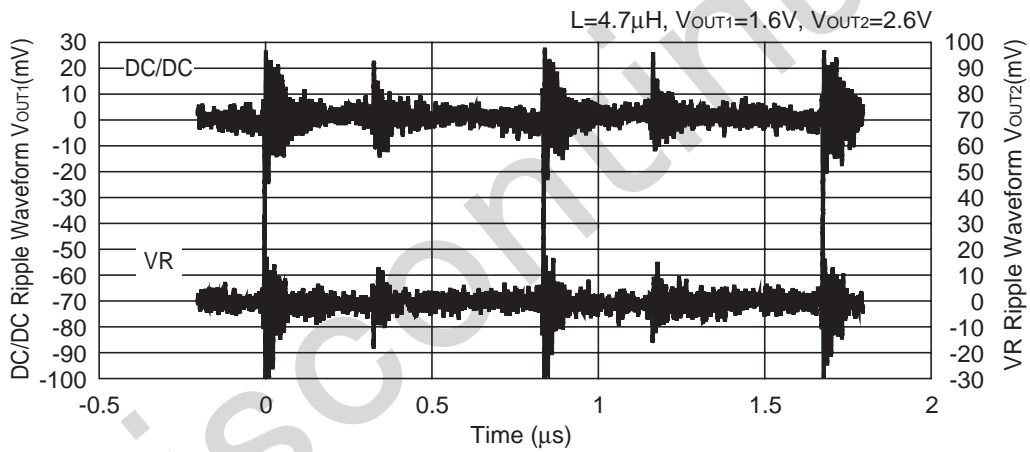
17) VR Load Transient Response (T_{opt}=25°C)

R5212D011A

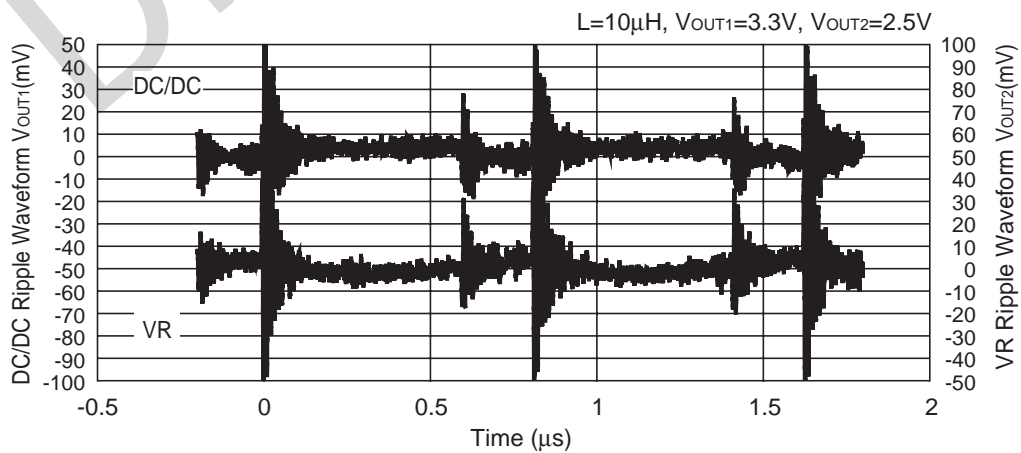


18) DC/DC, VR Ripple Waveform (C=10 μ F, V_{IN}=5V, I_{OUT1}=280mA, I_{OUT2}=150mA, T_{opt}=25°C)

R5212D011A

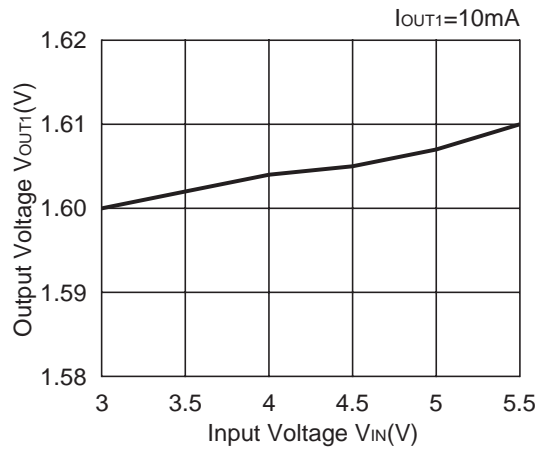


R5212D014C

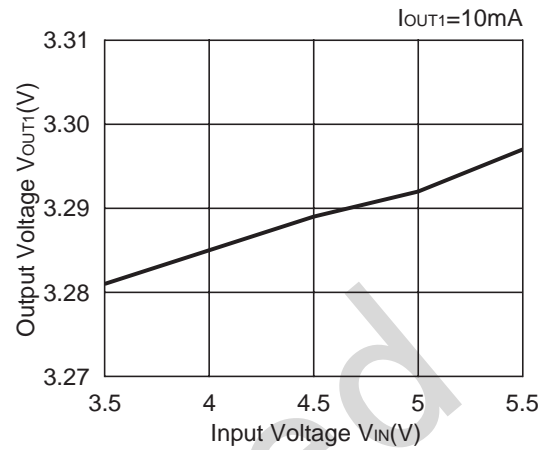


19) DC/DC Output Voltage vs. Input Voltage ($T_{opt}=25^{\circ}\text{C}$)

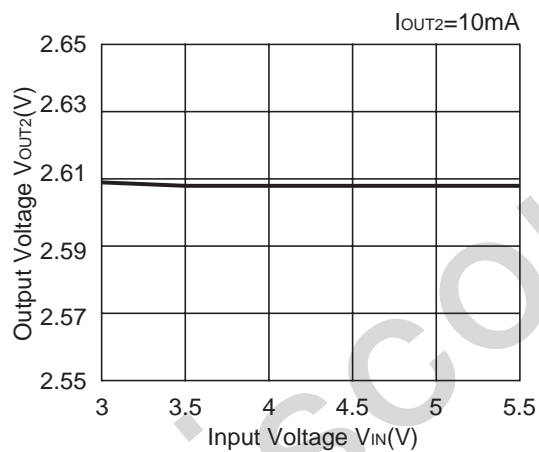
R5212D011A



R5212D014C

20) VR Output Voltage vs. Input Voltage ($T_{opt}=25^{\circ}\text{C}$)

R5212D011A





1. The products and the product specifications described in this document are subject to change or discontinuation of production without notice for reasons such as improvement. Therefore, before deciding to use the products, please refer to Ricoh sales representatives for the latest information thereon.
2. The materials in this document may not be copied or otherwise reproduced in whole or in part without prior written consent of Ricoh.
3. Please be sure to take any necessary formalities under relevant laws or regulations before exporting or otherwise taking out of your country the products or the technical information described herein.
4. The technical information described in this document shows typical characteristics of and example application circuits for the products. The release of such information is not to be construed as a warranty of or a grant of license under Ricoh's or any third party's intellectual property rights or any other rights.
5. The products listed in this document are intended and designed for use as general electronic components in standard applications (office equipment, telecommunication equipment, measuring instruments, consumer electronic products, amusement equipment etc.). Those customers intending to use a product in an application requiring extreme quality and reliability, for example, in a highly specific application where the failure or misoperation of the product could result in human injury or death (aircraft, spacevehicle, nuclear reactor control system, traffic control system, automotive and transportation equipment, combustion equipment, safety devices, life support system etc.) should first contact us.
6. We are making our continuous effort to improve the quality and reliability of our products, but semiconductor products are likely to fail with certain probability. In order to prevent any injury to persons or damages to property resulting from such failure, customers should be careful enough to incorporate safety measures in their design, such as redundancy feature, fire containment feature and fail-safe feature. We do not assume any liability or responsibility for any loss or damage arising from misuse or inappropriate use of the products.
7. Anti-radiation design is not implemented in the products described in this document.
8. The X-ray exposure can influence functions and characteristics of the products. Confirm the product functions and characteristics in the evaluation stage.
9. WLCSP products should be used in light shielded environments. The light exposure can influence functions and characteristics of the products under operation or storage.
10. There can be variation in the marking when different AOI (Automated Optical Inspection) equipment is used. In the case of recognizing the marking characteristic with AOI, please contact Ricoh sales or our distributor before attempting to use AOI.
11. Please contact Ricoh sales representatives should you have any questions or comments concerning the products or the technical information.



Ricoh is committed to reducing the environmental loading materials in electrical devices with a view to contributing to the protection of human health and the environment.

Ricoh has been providing RoHS compliant products since April 1, 2006 and Halogen-free products since April 1, 2012.

RICOH RICOH ELECTRONIC DEVICES CO., LTD.

<http://www.e-devices.ricoh.co.jp/en/>

Sales & Support Offices

RICOH ELECTRONIC DEVICES CO., LTD.

Higashi-Shinagawa Office (International Sales)
3-32-3, Higashi-Shinagawa, Shinagawa-ku, Tokyo 140-8655, Japan
Phone: +81-3-5479-2857 Fax: +81-3-5479-0502

RICOH EUROPE (NETHERLANDS) B.V.

Semiconductor Support Centre
Prof. W.H. Keesomlaan 1, 1183 DJ Amstelveen, The Netherlands
Phone: +31-20-5474-309

RICOH INTERNATIONAL B.V. - German Branch

Semiconductor Sales and Support Centre
Oberrather Strasse 6, 40472 Düsseldorf, Germany
Phone: +49-211-6546-0

RICOH ELECTRONIC DEVICES KOREA CO., LTD.

3F, Haesung Bldg, 504, Teheran-ro, Gangnam-gu, Seoul, 135-725, Korea
Phone: +82-2-2135-5700 Fax: +82-2-2051-5713

RICOH ELECTRONIC DEVICES SHANGHAI CO., LTD.

Room 403, No.2 Building, No.690 Bibo Road, Pu Dong New District, Shanghai 201203, People's Republic of China
Phone: +86-21-5027-3200 Fax: +86-21-5027-3299

RICOH ELECTRONIC DEVICES CO., LTD.

Taipei office
Room 109, 10F-1, No.51, Hengyang Rd., Taipei City, Taiwan (R.O.C.)
Phone: +886-2-2313-1621/1622 Fax: +886-2-2313-1623